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SOME OBSERVATIONS ON THE DEVELOPMENT OF ENDOGONE MALLEOLA HARK.

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(WITH PLATES 26 AND 27)

Species of *Endogone* are so rarely found in abundance that when, during September, 1921, a great quantity of *Endogone malleola* was found growing on soil and ground litter in a mixed deciduous woods near Lincoln, Nebraska, it seemed worth while to attempt some studies upon its development. It seemed especially desirable because there are no publications giving the details of development of any of the non-sexual species of *Endogone*, and it is the gross appearance of this type of *Endogone* that lead various workers to consider *Endogone* as an Ascomycete, sporangia having been mistaken for asci.

Specimens were sent to Dr. Roland Thaxter and to Dr. E. A. Burt for determinations. Both considered it to be what is known as *E. malleola* Hark. The reference of this form, and closely related forms, to *Endogone* is entirely provisional, as has been pointed out by Thaxter (8).

A large number of these fruits were fixed in Fleming's stronger solution and Gilson's fluid for future study, while others were used for germination and cultural studies. The fungus appeared again in September, 1922, and materials were fixed in Fleming's stronger solution and dilute chrom-acetic solution and others used for cultural work. The specimens collected in 1922 were not in as good condition as those of the 1921 collection, so little use was made of them in the morphological study.

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DESCRIPTION OF SPORANGIOCARPS

The sporangiocarps are whitish, rounded, or somewhat elongated bodies, about 1–4 mm. across (pl. 26, fig. 4). The upper surface is hemispheric, smooth or more or less convoluted, while the under surface is slightly depressed except where delicate strands of hyphae attach it to the substratum. In sectional view (pl. 26, figs. 9, 10, 12–14) the interior is found to consist of a compactly interwoven portion at the base, made up of closely septate hyphae, which also show many anastomoses. From this, other septate hyphae extend radially toward the surface and give rise to an outer region in which are found intermingled hyphae and sporangia. The sporangia are many spored and look much like those of a mucor, but lack a columella, as is true of *Mortierella*. A great deal of variation from the type given in Harkness' (5) original description was observed, and Dr. Thaxter (8) (also in personal letters) says that similar variations have been noted by him in other collections. Two quite distinct types of sporangiocarps were found which might be designated as small and large sporangial types.

In the small sporangial type the fructifications are almost hemispheric (pl. 26, figs. 9, 12, 13) and the sporangia average about 30 μ in diameter, running up to about 45 μ as a maximum. The sporangia in this type are usually terminal, but seemingly may be intercalary,[1] and are densely massed together toward the outside of the fruit. Each sporangium contains relatively few spores (pl. 27, fig. 14), averaging 10–13 x 12–15 μ, but occasionally there are very small (5 x 6 μ) and very large (20 x 33 μ) spores. Mixed with the sporangia are hyphae, terminating in somewhat moniliform cells, and these, together with the stalks of some of the sporangia which reach the surface, give the appearance of a delicate cobwebby peridium (pl. 26, fig. 11).

[1] In materials treated with potash and teased apart long filaments bearing 2–3 sporangia at their tips are frequently found. In rolling these over and over so as to examine all surfaces no traces of sporangiophores or scars left by sporangiophores can be found, in some cases, except for the basal sporangium. On the other hand similar chains of sporangia were found where sporangiophores were attached to each sporangium. The same conditions were observed in serial sections of sporangiocarps.

In the second or large sporangial type (pl. 26, figs. 10 and 14) the fructifications are often much flatter and in the sporangial region few intermixed hyphae are found. No traces of moniliform cells or superficial hyphae occur. The sporangia (pl. 27, fig. 15) are definitely terminal, much larger (50–70 μ) in diameter, and contain many spores. The spores in these larger sporangia are slightly smaller (7–10 x 10–13 μ).

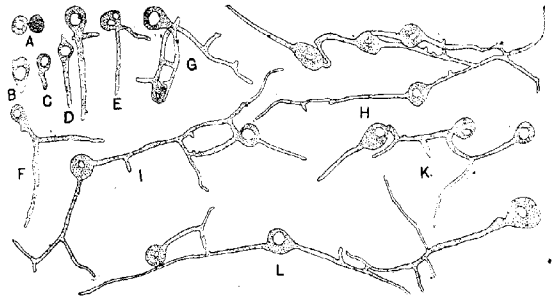

FIG. 1. Spore germination and anastomoses. × 300. *A*, Two spores; spore to right younger than spore to left. *B–G*, Spore germinations in soil extract hanging drop 18 hours old. *H–L*, Same cultures when 24 hours old.

The spores in earlier collections of both types were filled with a uniform, coarsely granular content (pl. 27, figs. 12 and 14), but later collections showed one or more large globules in each spore (pl. 27, fig. 15). Also see text fig. 1, *A*.

All collections made during 1921 showed both types of fructifications, with the small sporangial type predominating. During September, 1922, only the large sporangial type was found. The climatic conditions during the two seasons were very different. During 1921 the fungus appeared following a long period of extremely hot, wet weather. During the latter part of the summer of 1922 exceptionally hot, dry conditions prevailed, so that little could develop. It appeared in about a week following a few rainy days and as no more rains came no continued development was possible. These climatic differences possibly account for the variations in the appearance of the fructifications.

SPORE GERMINATION, PROTOPLASMIC MOVEMENTS, AND CULTURES

The spores germinate readily in water, soil extract, or in any of the various agar agar media tried (text fig. 1). One to several germ tubes develop from each spore in 8 to 16 hours. The germ tubes grow rapidly and in 18 hours appear as shown in text fig. 1, *B–G*. Wherever two or more spores are in close proximity to each other anastomoses occur. As the tubes elongate, granules which densely filled the spores move out from the spores into the hyphae. The growth is so rapid that one may easily see a streaming movement of the granules by the time the tubes are ten times the length of the diameter of the spore and often before the tubes are this long. As the anastomoses occurred, the dissolution of the intervening walls could easily be determined by the movement of granules from one hypha into the other, as from *x–y* in text fig. 1, *G*. When spores were grown in water or soil extract, hanging drops many more anastomoses occurred than when grown in more highly nutrient media. Text fig. 1, *H–L*, and pl. 26, fig. 6, show anastomosing germ tubes as developed in a soil extract, hanging drop 24 hours old.

As more and more of these anastomoses occur, larger hyphae develop, into which the contents of many spores are emptied (text fig. 2, *M*, and pl. 26, figs. 7 and 8). After the protoplasm has all been emptied out from the spore into the larger or distributive hypha, cross-walls are usually formed cutting off the empty portions. In hanging-drop cultures a few days old these distributing hyphae are easily followed for a centimeter or more, even across the entire circle of the cover of the hanging drop. They usually extend in almost straight lines only here and there, branching or anastomosing with other large hyphae similarly developed (pl. 26, figs. 7 and 8). (Fig. 8 shows the detail of the anastomosing and branching occurring in the lower central portion of fig. 7.)

In these larger hyphae the protoplasmic movement was extremely conspicuous and far more rapid than is ordinarily seen in plant cells. So rapid was the movement that it seemed impossible to determine the rapidity accurately, but granules were easily carried 50 μ per second in many cases, while movements of granules up to 20 or 30 μ per second were often seen. The protoplasmic

movements attained their maximum rapidity in cultures about 4 days old and continued at nearly the same rate till the drop dried out, usually about ten days.

In a few cases hanging-drop cultures were made from immature sporangia, and while the spores were well developed in most of the sporangia, the sporangial walls retained the spores. In such cases hyphae developed from the base of the sporangium (text fig. 2, *N*). These hyphae had the same characteristics as the large hyphae which arose from the anastomosing of germ tubes coming from the spores. As many of the spores in the sporangia became empty, it seemed probable that the spores germinated and their tubes anastomosed within the sporangium.

In all cases where vigorous streaming occurred there was a main current running in one direction, but small reverse streams could be seen also, showing a definite cyclosis. These movements are indicated by arrows in text fig. 2.

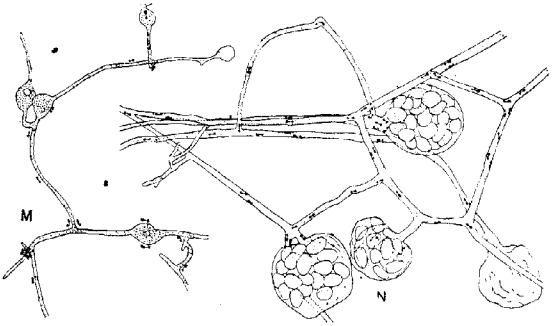

FIG. 2. Distributive hyphae and protoplasmic movements. *M*, an early stage in the formation of distributive hyphae. × 300. *N*, Distributive hyphae emerging from sporangia. × 250. Arrows indicate protoplasmic movements.

Germinating spores, fixed and stained upon the cover-glass, showed the spores and the hyphae coming from them to be multinucleate.

Since the spores germinate so readily, numerous attempts were made in 1921 to obtain the fungus in pure culture, but without success. All fruits examined in both fresh material and stained

sections showed an abundance of bacteria mingled in with the hyphae of the fruit body of the *Endogone*. A species of *Fusarium* was also abundant and in no case was it possible to separate the *Endogone* from the bacteria and *Fusarium*. In these, impure culture masses of moniliform cells appeared in a number of cases. They arose as lateral branches of distributive hyphae (text fig. 3, *O*) and soon increased in number so greatly as to form masses up to a millimeter in diameter and appearing superficially like mature sporangial fruit bodies. The branching and appearance of these moniliform cells is shown in text fig. 3, *P–S*. Text fig. 3, *T*, shows one of these masses about ½ mm. in diameter that developed in a hanging-drop culture. The mass was developed between the hyphae and the cover slip. During its development the protoplasmic streaming was very rapid from all sides toward the mass of moniliform cells, while the reverse movement was so slight that at times it was almost impossible to observe it. Similar masses appeared upon some agar cultures and were kept moist for months, but no further development resulted. Some of these masses appeared below the surface of the agar medium, while others were entirely superficial.

Because of the failure to get pure cultures and sporangial development in 1921 a second effort was made to obtain *Endogone* in pure culture in 1922. Because of the climatic conditions prevailing this last season all of the sporangiocarps were young and there had been little chance for infection. As the spores did not separate readily from the sporangia, no attempts were made to get one-spore cultures, but fragments from the interior of sporangiocarps planted upon agar media gave an abundance of mycelium, showing all of the characteristics of *Endogone* mycelium obtained from germinating spores the previous season. About 20 separate cultures were thus obtained. The appearance of such culture is shown in pl. 26, fig. 1. A number of these cultures have been grown upon corn-meal agar, corn-meal agar + dextrose, soil-extract agar, soil-extract agar + peptone, beef extract + glucose agar, sterile soil, sterile leaf cover, sterile soil and leaf cover + peptone, sterile soils and leaf cover + sodium nitrate, sterile soil and leaf cover + calcium nitrate, corn-meal mush, bean pods, sawdust,

etc. Vigorous development resulted on all except the last two. In most cases clumps of moniliform cells appeared in about a week to ten days (pl. 26, figs. 2 and 5), and in many cases these masses grew to a size and form indistinguishable to the naked eye from the sporangial fructifications, but no sporangia have ever developed. The clumps of moniliform cells occurred most abundantly on corn-meal mush, while the development on the various soil cultures appeared more nearly like sporangial fructifications.

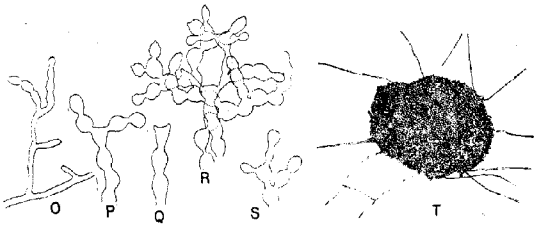

FIG. 3. Development of moniliform cells and masses. *O*, Origin of moniliform cells. *P–S*, Branching of moniliform hyphae. *T*, A mass of moniliform cells ½ mm. in diameter with hyphae from which it developed. *O–S* × 300; *T* × 50.

Various attempts were made to test the possible effect of heat, moisture, and light upon the development of these clumps of moniliform cells. Cultures were held at different temperatures, at fluctuating temperatures (cooler at night and warmer during day), were allowed to dry out and then watered, were kept in direct and diffuse light, etc., but no combination tried changed the development of these clumps.

The different cultures obtained showed considerable variation in vigor of growth and development of moniliform cells. Some strains grew rapidly and developed large masses of moniliform cells, while others grew very slowly and developed very few or no clumps of moniliform cells. Others showed so little vigor that they soon died. Various attempts were made while the cultures were fresh to contrast strains in the hope that this might stimulate further development, but obtained no results. Later a series of all possible crosses of nine strains that survived was made, but no further development resulted.

In sections the interior of these masses is found to be made up of interwoven and anastomosing hyphae resembling those on the on the outside closely resemble those found on the outside of some very young sporangial fructifications, as will be described later, but nothing resembling the radiating hyphae that are so prominent in the sporangiocarps are to be found. The masses as formed in cultures have a firm, solid consistency throughout, as would result from the dense interweaving of the moniliform branches. Cross-walls may be put in, in the older moniliform cells, but these cells never separate from each other to form spore-like bodies. Two possibilities in regard to these masses of moniliform cells suggest themselves to the writer. The one is that these are possibly sclerotia, as the cells become densely filled with oil globules, and the other, and more probable, is that they are aborted fructifications and that the proper stimulus for sporangial development is lacking under cultural conditions. That the fructifications have only been found in September also adds weight to this idea.[2]

DEVELOPMENT OF SPORANGIOCARPS

The youngest sporangiocarp found in sectioning the fixed materials was of the small sporangial type and is shown in pl. 26, fig. 17. On one side (pl. 26, fig. 17, right, and fig. 18) are moniliform cells and on the other (pl. 26, fig. 17, left, and fig. 16) are young sporangia with spores. In between these (pl. 26, fig. 17, top, and fig. 15) intermediate (possibly aborted) stages in the development of the sporangia are found. The first sporangia appear to arise directly from the enlargement of moniliform cells, but so little material in a very young condition was available that a positive statement can not be made. Often, as in this case, the sporangiocarps were in poor condition before fixation, as is indicated by a less dense protoplasmic content and by the presence of masses of bacteria in the spaces. The bacteria appear as dark masses be-

[2] The writer was absent from Lincoln from the middle of June until Sept. 1, 1922. A student in the department made repeated visits to the woods where it has been found but failed to find any. The possibility exists, however, that it might have been overlooked if present in very small amounts. During the summer of 1923 the writer made frequent visits to the woods where *Endogene* had been obtained previously, but found none until the middle of August, when one lone sporangiocarp was discovered. Cultures from this resulted as previously.

tween filaments and around sporangia in the photographs (figs. 15–18). The fixing agent (Gilson's) also caused much plasmolysis in the outer regions.

The examination of sections of many fructifications of the small sporangial types indicates that as the sporangiocarps grow older other sporangium-bearing hyphae grow up from below and intermingle with the sporangia that seem to be formed from moniliform cells. These have only terminal sporangia. The stalks often grow out beyond the other sporangia and backward so that the sporangium rests upon the surface of the fructification. These stalks are often so abundant as to give the appearance of a cobwebby peridium under a hand lens. Development in a sporangiocarp does not seem to be uniform. One side is commonly much younger than the other. Young sporangia are especially often found near one margin, but may be found in various positions on the fructification. This irregular continuation of growth probably gives rise to the convoluted appearance often observed.. No relationship between age and size of sporangiocarps was observed.

It has been very difficult to form any idea as to stages in the development of the large sporangial types. Some fructifications were found that consisted of hardly more than a dozen very young sporangia. They seemed to consist of long-stalked sporangia, the sporangiophores radiating from a small weft of hyphae at the base. One of these fructifications is shown in pl. 26, fig. 3. Other fructifications no larger than this showed mature sporangia. The larger fructifications seem to be only larger masses of sporangia arising from larger wefts of mycelia. They possibly represent rapidly developed fructifications formed under optimum conditions.

DEVELOPMENT OF SPORANGIA

The development of the sporangia appeared to be the same in both types of fructifications. The young sporangia are densely filled with a multinucleate protoplasm (pl. 27, figs. 1–3). The protoplasm in a hypha, leading to a sporangium, forms a loose mesh work, and that in a sporangium a slightly closer mesh work. A cross-wall is soon put in which separates the sporangium from the hypha that bears it (fig. 2). The cross-wall may be below or near the sporangial enlargement. Fig. 4 shows what appears

to be a young intercalary sporangium. As the sporangium enlarges (fig. 3) the protoplasmic meshes become smaller and smaller till they are only visible with an oil-immersion objective. Cleavage begins at this time. The furrows start near the periphery and extend inward. Figs. 6 and 7 in pl. 27 show two sections through a young sporangium and fig. 8 a section of another sporangium showing a slightly later stage in cleavage. Figs. 9–11 are three successive sections through a slightly older sporangium showing later stages in the development of the furrows. The protoplasm soon becomes divided into masses of various sizes and shapes (figs. 5 and 13). During the early stages of cleavage the furrows are densely filled with a slime that takes the saffranin and haematin stains very readily. The slime soon disappears and during later stages (pl. 27, figs. 5, 9–11, and 13) the furrows seem entirely free from slime. The nuclei retain the same characteristics during all stages of sporangial development. They are densely granular with several nucleoli (below in fig. 10).

In most sporangia the spores become sphaeroidal and almost completely fill the sporangium (pl. 27, figs. 14 and 15), but in some sporangia large masses of protoplasm seem to escape further cleavage and thus give rise to the very large spores often observed in examining mounts from fresh material. The mature spores are always multinucleate (pl. 27, fig. 12), the nuclei having the same structure as those observed in the sporangium during its development.

The development of the spores in the sporangia more closely resembles that of *Sporodinia* (Schwarze (7)) than any other form for which we have a full account. Vacuoles at no time seem to take any direct part in the formation of the cleavage furrows.

INDICATIONS OF RELATIONSHIP

The structure of the hyphae and the method of sporangium and spore formation all point definitely to a phycomycetous relationship. The only characteristic that is not definitely phycomycetous is the septation of hyphae in the sporangiocarps (and occasionally in older hyphae), but similar septations occur in the sporangiophores of *Sporodinia grandis* and the older mycelia of certain mucors. Among the Phycomycetes its closest relatives are to be

found among the Mucorales. The absence of the columella at once suggests *Mortierella,* and in looking over papers on *Mortierella* one must be impressed by the many similarities between *Mortierella* and Endogone malleola. Especially strikingly was this observed in Bachmann's (2) account of spore germination and the development of anastomoses by *M. van tieghemi.* Kauffman (6) in *M. bainiere* observed the development of somewhat moniliform enlarged cells closely resembling structurally the moniliform cells formed in culture of *E. malleola.* His cells were formed in the media, while in *E. malleola* these cells may be formed in the media or on the surface of the culture and are developed in greater abundance. The presence of such masses does not seem to be characteristic of the genus *Mortierella,* however, as Dauphin (4) does not mention them in his discussion of the genus.

No trace of a sexual stage was found, nor have any been found, for any species of *Endogone* of this sporangial type. Thaxter (8) has found one case through which he could definitely connect the chlamydosporic types of *Endogone* with the sexual types, but whether a close relationship exists between the sexual types of *Endogone* and the sporangial types can only be settled by further observations. In this connection, however, it might be noted that both Atkinson (1) and Bucholtz (3) from their work on sexual types conclude that these are closely related to *Mortierella,* and Bucholtz (3) and Thaxter (8) point out also the probable relationships between these sporangial types and *Mortierella.* The writer's observations confirm this supposition. Since all types of *Endogone* show such definite relationships to *Mortierella,* it seems probable that the sporangial types also may be shown to be only stages in the development of sexual *Endogones.* With the information at hand, it seems as if *Endogone* should be removed from the Hermiascineae, where it has been placed by many (see Atkinson (1), p. 11, for summary), and placed in the Mucorales.

SUMMARY

1. There is great variation in the sporangiocarps of *E. malleola.* Large and small sporangial types of fructifications are noted.

2. The spores germinate readily in water.

3. By means of anastomoses larger distributive hyphae develop.

4. Protoplasmic movement is very rapid in the distributive hyphae.

5. Large masses of firmly interwoven moniliform cells superficially resembling sporangiocarps develop on cultures, but true sporangiocarps were never produced.

6. The development of the sporangia is entirely phycomycetous.

7. A close relationship between *E. malleola* and *Mortierella* is noted.

I wish to express my indebtedness to Dr. Roland Thaxter for suggestions during the progress of my work and for reading a first draft of this paper and adding more helpful suggestions. Thanks are also due Dr. Thaxter and Dr. E. A. Burt for identifications and Prof. T. J. Fitzpatrick for proof-reading the paper.

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DESCRIPTION OF PLATES

PLATE 26. PHOTOMICROGRAPHS

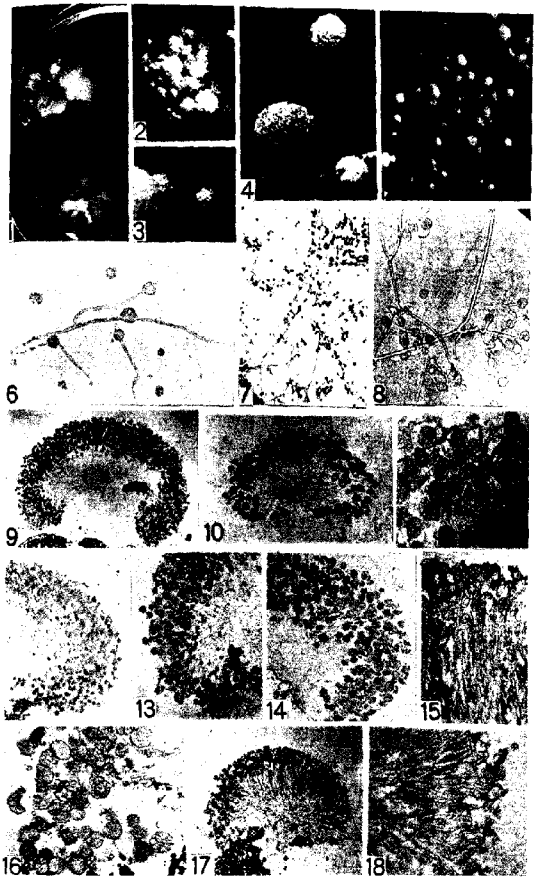
1. Culture of *Endogone* on corn-meal agar when about a week old. Moniliform cells appearing; × 5/9.

2. Higher magnification of moniliform cells on culture shown in fig. 1; × 12.

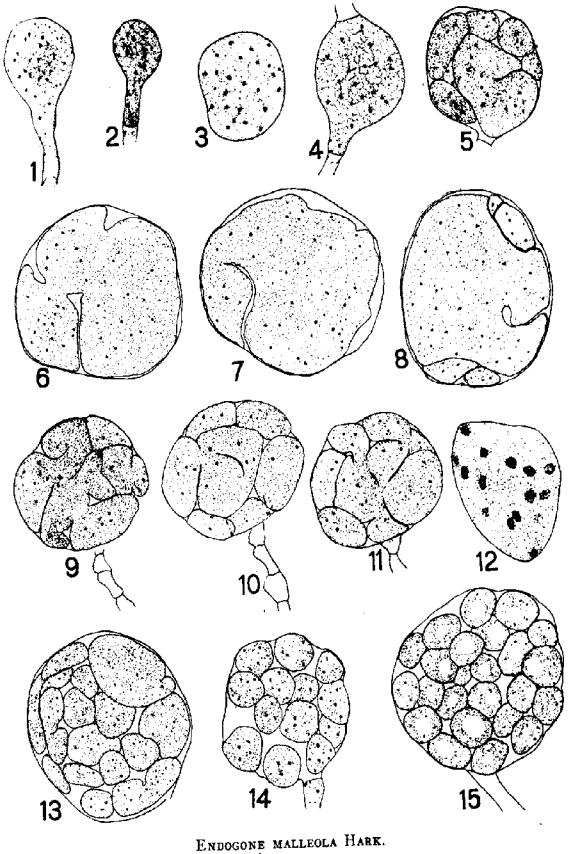
3. Very small sporangiocarp; × 12.

4. Mature sporangiocarps; × 7.

5. Masses of moniliform cells on older agar culture; × 7.



ENDOGONE MALLEOLA HARK.



ENDOGONE MALLEOLA HARK.

6. Hyphal anastomoses in 24 hours old hanging drop culture; × 136.

7. Portion of a thickly "seeded" hanging drop culture 2 days old; × 55.

8. Higher magnification of lower central portion of field seen in fig. 7 showing branching and anastomosing of distributive hyphae; × 136.

9. Median cross section of typical mature sporangiocarp; × 15.

10, 12, 13, 14. Parts of sections of mature sporangiocarps showing variations in size of sporangia and arrangement of parts; × 30.

11. Portion of outer layer of a sporangiocarp of the small sporangial type to show superficial hyphae; × 136.

15–18. A young sporangiocarp of the small sporangial type (17) showing to the left (16) sporangia in all stages of development, to the right (18) radiating hyphae ending in moniliform cells and to the center (15) a transition from moniliform cells to young sporangia; fig. 17 × 30; figs. 15, 16, 18 × 136.

PLATE 27. CAMERA LUCIDA DRAWINGS

1. Young sporangium before formation of cross wall separating it from sporangiophore; × 555.

2. Young sporangium cut off by cross wall; × 555.

3. Larger sporangium before cleavage begins; × 555.

4. Intercalary cell showing characteristics of young sporangium; × 555.

5. Sporangium showing late stage in cleavage; × 555.

6, 7. Two sections of sporangium showing a very early stage in cleavage; much slime was present in furrows; × 555.

8. Slightly later stage in cleavage of sporangium; × 555.

9, 10, 11. Three sections of the same sporangium showing development of cleavage furrows; × 555.

Two nuclei and cytoplasmic structure shown below in fig. 10; × 1500.

12. One spore; × 1500.

13. Late stage in cleavage; × 555.

14. Mature (young) sporangium (small type); × 555.

15. Mature (older) sporangium (large type); × 555.

DECAY OF LUMBER AND BUILDING TIMBERS DUE TO PORIA INCRASSATA (B. & C.) BURT

C. J. HUMPHREY

(WITH PLATES 28–30)

INTRODUCTION

During the past twelve years the writer has been accumulating information and material on the decay of timber used for building purposes. These investigations have covered the entire United States. Part of the data have been secured through correspondence at the Madison Laboratory of the Office of Forest Pathology, coöperating with the Forest Products Laboratory, which has been the clearing-house for most of the inquiries of this character made to the Federal government, and part by special field work, mainly throughout the eastern and southern states and the Pacific Coast region. These investigations cover lumber yards and all types of buildings from the simplest structures to large industrial plants.

The greatest economic losses from decay in buildings probably occur in those structures where the air is highly humidified either by artificial means or through manufacturing processes, such as in weave sheds and dye sheds in the textile industry, paper mills, etc. A limited number of fungi have been found doing extensive damage in this type of buildings, but *Poria incrassata,* the fungus here under discussion, has not yet been found developing under these conditions, although it is frequent in other buildings.

The decay due to *Poria incrassata* is quite similar to that produced by *Merulius lachrymans* and has probably been frequently confused with it, especially since the fungus is often found in a sterile condition. In common with *Merulius lachrymans,* infections first start in moist, cool situations, preferably on timber beneath floors which is either in contact with the ground or close to it. On the whole it is of greater economic importance than any of the members of the Merulius group in the United States.

HISTORICAL

In his monograph on "Merulius in North America,"[1] Dr. E. A. Burt first used the name *Poria incrassata*. As synonyms of this he includes *Merulius incrassatus* B. & C. described in 1849 from pine stumps in South Carolina, *Merulius spissus* Berk., also from South Carolina (1872), and *Polyporus (Poria) pineus*, described by Peck from wood and bark of pine, Selkirk, New York, in 1888. In 1913, Dr. Adeline Ames described a fungus from Auburn, Alabama, which was decaying pine and cypress woodwork in the Engineering Building of the Alabama Polytechnic Institute, calling it *Poria atrosporia* Ames on account of the dark spores. Since then the fungus has not appeared in literature in connection with the decay of timber.

The writer has compared the types, or fragments of the types, of all the above species. Although the hymenium is for the most part disorganized, and the dry specimens collapsed and friable, there can be no doubt that we are dealing with but a single species. The spores are copious in all the collections and are similar in color, shape, and size. Representative specimens from the writer's collections of *Poria incrassata* were also referred to Miss E. M. Wakefield at the Kew Herbarium, London, who kindly compared them with the type of *Merulius incrassatus* B. & C. Her valued opinion likewise confirms the findings of the writer in this respect. The name *Poria incrassata* (B. & C.) Burt, having priority, must then be used to designate the fungus.

DESCRIPTION OF THE FUNGUS

No adequate description of the fungus in the fresh condition has ever been published. Berkeley and Curtis (Grevillea 1: 70. 1872) state that *Merulius incrassatus* is "dirty white and slightly silky; substance thick, fleshy, folds forming minute shallow brownish pores." On the same page in Grevillea, Berkeley describes *Merulius spissus* as "several inches across, at first membranaceous with shallow pale pores about 1/24 of an inch in diameter, then much elongated and forming a dark brown mass." Peck (New York State Mus. Rept. 41: 78. 1888) states that *Poria pinea* has

[1] Ann. Mo. Bot. Gard. 4: 305–362. *pl. 20–22, figs. 1–39.* Nov., 1917.

"the thin subiculum and margin whitish, sometimes tinged with yellow; pores . . . dingy whitish, becoming blackish where bruised or wounded, the whole plant becoming blackish or blackish-brown in drying." Ames, working with dry material, described *Poria atrosporia* (Bot. Gaz. **55**: 397–399. 1913) as "pale umbrinous," with "pores deep fuligineous because of the abundance of dark spores."

These descriptions are entirely too meager for one to gain a true conception of the fungus, and the only satisfactory way to ascertain the identity of the above species was to make a detailed comparison of the type or co-type material. The organism assumes many different aspects (Pls. 28–30) both in the sterile and fruiting condition, in accord with changes in the environment. The writer has found the species in all stages of development, but only in rare cases are all the characters combined in a single collection.

The most striking character of the fresh fruit-bodies is the color, which varies in specimens developed under partial illumination, such as obtains in the woods or in partially lighted basements, from orange to pale olivaceous (Pl. 28, Fig. 1). When growing entirely in the dark beneath floors no trace of orange is present. However, when the mycelium grows through the cracks in the floor into a lighted room, it may form cushions of orange mycelium. This has been noted in two instances, the one case in a warehouse and the other in an empty lumber storage shed open in front. Orange mycelium has also been observed in partially illumined basements. Where fructifications have been observed on the upper surface of the floor, these have been brown.

The following field notes present the characters and appearance of the fungus when developing under different conditions:

Field No. 6671. On side of rotten prostrate charred trunk of *Thuya plicata* along roadside in woods, Shelton, Washington, October 4, 1910.

Plant effused in elongate patches up to 12 inches or more long, 4 to 8 inches wide, and 1.3 cm. thick, much contorted when overgrowing a mossy surface. Young plants orange with a pallid-yellowish margin. When mature they become pale-olivaceous with the ultimate margin pallid-yellow and the adjacent surface orange, shading into olivaceous over the mature pore surface. Margin determinate but irregular, tomentose.

Pores subangular or linear-elongate and then up to 2 mm. in length and

1/2 to 2/3 mm. in width, up to 7 mm. deep, orange tinged over the lower half. Dissepiments entire, thick, fleshy, much thicker than the diameter of the pores in young plants.

Subiculum 1 to 8 mm. thick, fleshy-fibrous, hygrophanous, breaking with a succulent, brittle fracture; with a narrow orange zone followed by a narrow whitish zone just beneath the pores contrasting with the hygrophanous lower layers. At the thickest portion white over the lower half and hygrophanous-white above.

No. 7833. Beneath Douglas fir flooring laid over sawdust. Lumber storage shed near Seattle, Washington. October 13, 1915.

Plant succulent, fibrous-fleshy, moderately tough, easily separable from the substratum, light olive-gray (R)[2] when young and fresh, becoming near to sepia (R) as it matures, and finally brownish-black or black (Pl. 28, Figs. 1–3; Pl. 29, Fig. 1).

Pores up to 1 cm. deep, averaging 2 to a millimeter, subangular to somewhat sinuous, olivaceous at edge, sepia within. Dissepiments much interrupted and of uneven heights.

Subiculum 2 to 3 mm. thick, subgelatinous, with a fibrous, whitish to cremeous layer just beneath the pores, otherwise watery-brown, somewhat lighter in color than the pores, attached to substratum by conspicuous tufted fibrils which make the plant readily separable from its host. In the mature plant there was no suggestion of orange, although the mycelium growing up through the cracks in the floor was distinctly of this color. On drying, the plant becomes very light in weight, and coarsely frustulate. In this condition it is very fragile and easily detached from the substratum on jarring. On account of its succulent character when fresh, it is soon destroyed by molds and insects.

When the fungus fruits on the upper surface of flooring or on the exposed surface of interior finish in buildings, the fructifications are much firmer in texture (Pl. 28, Figs. 4, 5, and 6), and often develop a thick whitish subiculum of compact vertical hyphae. This cracks widely in drying, the context then being in sharp contrast to the brownish to blackish-brown pore surface. The margin in such cases is broadly sterile, puberulent, dirty-whitish, sometimes tinged with orange. The youngest pores are mere pits, which are very shallow. An immature collection (Pl. 28, Fig. 8), with the pores just forming, taken from beneath a building in Washington, D. C., varied, in the dry condition, from ochraceous-buff (R) to cinnamon-buff (R) over the pore surface, with a broad sterile margin near to light-buff (R).

Other collections, more or less abortive in character, remind one of compact liver (Pl. 28, Fig. 5), both in color and consistency. Such specimens shrink markedly in drying, separate from the sub-

[2] Ridgway, Robert. Color standards and color nomenclature, 1912.

stratum, especially at the margins, and become unrecognizable except to one particularly familiar with the organism.

The mycelium frequently forms extensive fan-shaped sheets (Pl. 30, Figs. 1 and 3) particularly when developing between two adjoining timbers. This mycelium is whitish when young, but becomes tinged with yellowish-olive to brownish as it ages. Such sheets of mycelium are very characteristic and are present on many of the samples of decayed building timbers sent in to the laboratory for identification. In conjunction with cultures derived from the infected wood they furnish a ready means of identifying the organism.

In some collections rhizomorphs are present. When young these are white and very small (Pl. 29, Fig. 2). As they mature they become brown to brownish-black and are frequently flattened, intimately imbedded in the mycelial sheets, and closely appressed to the decayed wood (Pl. 29, Fig. 3). They are largest near the ground and may appear as heavy root-like growths which sometimes spread out as a foot-like attachment where they arise from the soil. Only rarely have the smaller strands been observed originating from the margin of the fructifications. Flask cultures of the fungus on wood (Pl. 30, Fig. 2), however, produce an abundance of the smaller white strands, which definitely proves their association with the species. The large brown rhizomorphs associated in nature with the mycelial sheets likewise demonstrate their organic connection with this species. This has been further verified by positive tissue cultures directly from a rhizomorph.

In structure the larger strands are very similar to the rhizomorphs described and figured by Falck [3] for *Merulius lachrymans*. They are composed of more or less parallel hyphae, the outer cortical layers being dark brown and thick walled and the medulla consisting of hyphae of varying size, many of these being differentiated into large conducting tubes (Pl. 29, Figs. 4 and 5).

The spores are very characteristic. They are elliptical to somewhat oval (Pl. 29, Fig. 6) and vary in color from dusky-olivaceous to dusky-brown under the microscope. In mass they are Prout's

[3] Falck, Richard. Die Meruliusfäule des Bauholzes. *In* Möller, A. Hausschwammforschungen, Heft. VI, p. 172 et seq., pl. 10, 1912.

brown (R). The more prevalent sizes are 6.5–7 x 8–10 μ. No other species of *Poria* is known to produce spores of this type.

The writer has had no opportunity of examining the structure in a fresh condition, and since the fungus dries to a collapsed, fragile mass it is difficult to study. In dry specimens, as Burt indicates, the tramal hyphae have a close, parallel arrangement and are usually brownish-tinged, along with the rest of the context. In a narrow layer just beneath the pores the hyphae are compact and in some cases have a tendency to parallel arrangement in the direction of the pores. As they approach the substratum they become loosely interwoven and frequently distinctly brownish.

The odor of the dry material is very marked in the case of the more succulent fruit-bodies, and reminds one of drying slippery-elm bark or certain of the fleshy Hydnums in the dry state.

CULTURE STUDIES

Spore germination tests with *Poria incrassata* have never been successful, since there was no opportunity in the field to work with fresh spores. Fruit-bodies sufficiently fresh for casting spores have only been met with four times and the spores obtained did not prove viable after returning to the laboratory several weeks later. Brown spores are, as a rule, difficult to germinate. In the case of *Merulius lachrymans*, it has been found, however, that freshly cast spores will germinate readily on malt agar, and this may be the case also with *Poria incrassata*.

Many pure cultures have been made, however, from decayed wood and in one case from a rhizomorph. These have been secured from about fifteen sources. None of the cultures have yielded fructifications of even an abortive type. They do, however, in some cases show the characteristic orange color reaction of the fungus in a minor degree.

Young cultures are pure white. On malt-extract agar an abundant mycelium is produced which usually takes on more or less of a radiate, strand-like character (Pl. 29, Fig. 7). As the cultures age they become somewhat tinged with yellowish-olive and occasionally at the upper limits of growth in a test tube or flask they may become orange-tinged. On wood in flasks they produce a

moderate white growth with numerous small, white strands closely appressed to the wood.

The rate of growth at different temperatures has been determined, using malt-extract agar of the following composition:

Extract of 1 pound lean beef in distilled water	1000 cc.
Löfflund's malt extract	25 gms.
Agar-agar	20 gms.

(Carefully filtered, but reaction not adjusted.)

Twenty cubic centimeters of the medium were poured into a 100-mm. Petri-dish and inoculated at the center with a small rectangle of mycelium with adhering agar cut from another Petri-dish. The cultures were prepared in duplicate and incubated for 4 weeks at 12°, 16°, 20°, 24°, 28°, 30°, 32°, and 34° Centigrade. The growth was measured at intervals of a week and recorded as radial growth in millimeters. The results are shown in Table 1.

TABLE 1

EFFECT OF TEMPERATURE ON MYCELIAL GROWTH OF *Poria incrassata*

Temperature (Deg. C.)	Age of inoculum (Days)	Radial growth in millimeters				Character of growth
		1 wk.	2 wks.	3 wks.	4 wks.	
12	—	0	3.5	5.5	9	Fluffy white; somewhat radiate.
16	15	6	16	27	42	Fluffy-radiate; white; somewhat zonate.
20	20	9	33.5	47+	—	Fluffy-radiate; white, creamy at center; somewhat zonate.
24	—	14	47	—	—	Fluffy-radiate; white
28	20	20	47+	—	—	Fluffy-radiate; margin white, older growth fawn to pinkish-violet.
30	15	30	37	47+	—	Fluffy-radiate; margin white shading into brownish then violet over center.
32	—	9.5	21	32.5	46	Fluffy-radiate; at first white, then margin white, shading into yellow and finally pinkish-cinnamon over center.
34	21	0	0	0	0	

In Petri-dish culture the fungus shows predominantly a fluffy-radiate growth which will cover a 100-millimeter dish in about ten days at 28° C., which appears to be the optimum for the fungus, although growth is nearly as good at 24° C. The color

changes, varying from yellow to pinkish-cinnamon as the mycelium ages, are quite conspicuous at temperatures of 28° C. and above.

The action of the fungus on various woods, comprising representatives of thirteen genera of conifers and twenty-five genera of broadleaf trees, has been tested by means of laboratory cultures in 2-liter Erlenmeyer flasks (Pl. 30, Fig. 2). The cultures were prepared as follows:

A quantity of small spruce and hemlock or mixed hardwood blocks, depending on whether coniferous or broadleaf species were under test, were soaked in water to saturation and sterilized in the autoclave at 15 pounds steam pressure for about 3 hours. This treatment forced out the excess water and put the blocks in good moisture condition for decay. A layer of these was then placed in the bottom of the flask. On top of these were placed from ten to twelve of the blocks which it was desired to test. These were, as a rule, 2 inches long and ¾ x ¾ inch in section. They had previously been dried at about 102° C. for 48 hours and weighed.

After the insertion of the test blocks, another layer of culture blocks was added to the flask, together with a pledget of wet cotton. The flasks were then capped with oilcloth and cotton and sterilized on three successive days at 100° C. for periods of 45, 30, and 30 minutes, respectively. They were inoculated by emptying into the flask a culture of the fungus developing on a bean pod. The tests were run for two years, but since a number of the flasks required reinoculation and the further addition of water several months after starting, the effective test period for these was actually less than the period indicated.

At the end of the period the test blocks were removed, dried as before, and weighed. The resulting loss in weight was taken as the criterion of decay under the conditions of test outlined, the percentages being computed on the basis of the original, dry weight. The results on the heartwood are given in Tables 2 and 3. In judging the condition of the wood it should be kept in mind that losses of 50 per cent and over mean that the timber was thoroughly decayed, and, as a rule, was sufficiently friable when dry to be pulverized between the fingers.

TABLE 2

HEARTWOOD OF CONIFEROUS SPECIES AGAINST

Poria incrassata

Species	Laboratory No.	Maximum loss in weight in 24 mos. (per cent)
Abies amabilis, Silver fir	118	47.8
Abies concolor, White fir	83	34.4
Abies grandis, Lowland white fir	224–16	43.5
Chamaecyparis lawsoniana, Port Orford cedar	319–76	39.6
Chamaecyparis nootkatensis, Alaska cedar	318–4	1.8
Juniperus californica, California juniper	142	34.8
Juniperus occidentalis, Western juniper	121	56.8
Juniperus pachyphloea, Alligator juniper	463–16	24.2
Larix europaeus, European larch	126	51.5
Larix occidentalis, Western larch	122–	46.4
Libocedrus decurrens, Incense cedar	318–11	0.9
Picea canadensis, White spruce	60	37.0
Picea engelmanni, Engelmann spruce	15–25	19.4
Picea rubens, Red spruce	226–84	19.4
Picea sitchensis, Sitka spruce	325–88	24.6
Pinus contorta, Lodgepole pine	10–2	59.8
Pinus echinata, Shortleaf pine	203–1	38.7
Pinus lambertiana, Sugar pine	122	24.2
Pinus monticola, Western white pine	224–2	43.3
Pinus palustris, Longleaf pine	176–38	55.2
Pinus ponderosa, Western yellow pine	224–21	70.2
Pinus resinosa, Norway pine	127	54.6
Pinus rigida, Pitch pine	156	57.8
Pinus strobus, White pine	120	31.2
Pseudotsuga taxifolia, Douglas fir	354–5	37.2
Sequoia sempervirens, Redwood	.....	28.6
Sequoia washingtoniana, Bigtree	40	37.5
Taxodium distichum, Bald cypress	14	30.1
Taxus brevifolia, Pacific yew	263–	8.9
Thuya occidentalis, Northern white cedar	124	42.5
Thuya plicata, Western red cedar	224–8	40.8
Tsuga canadensis, Hemlock	226–9	21.0
Tsuga heterophylla, Western hemlock	13–4	13.4
Tsuga mertensiana, Mountain hemlock	136	29.0

In presenting these durability figures, the writer does not wish to draw any comparison between the different species, since the cultures were not under sufficiently uniform control, particularly of moisture, to warrant it. The point to be emphasized is that we are here dealing with an omnivorous saprophyte which is capable of attacking and destroying almost all of the commercial woods of

TABLE 3

DURABILITY OF THE HEARTWOOD OF BROADLEAF SPECIES AGAINST *Poria incrassata*

Species	Laboratory No.	Maximum loss in weight in 24 mos. (per cent)
Acer ***macrophyllum,*** Broadleaf maple	160	67.5
Acer ***saccharinum,*** Silver maple	135	66.4
Aesculus ***octandra,*** Yellow buckeye	149	77.3
Amelanchier ***canadensis,*** Serviceberry	226–102	75.0
Betula ***lenta,*** Sweet birch	197–27	73.6
Castanea ***dentata,*** Chestnut	245–	19.6
Catalpa ***speciosa,*** Hardy catalpa	104	27.3
Celtis ***occidentalis,*** Hackberry	211–	76.2
Fagus ***atropunicea,*** Beech	.....	...
Fraxinus ***americana,*** White ash	256–3	68.6
Fraxinus ***biltmoreana,*** Biltmore ash	161–	67.4
Fraxinus ***lanceolata,*** Green ash	223–4	63.2
Fraxinus ***nigra,*** Black ash	219–	75.2
Gleditsia ***triacanthos,*** Honey locust	368–22	62.6
Hicoria ***glabra,*** Pignut hickory	72439	67.2
Hicoria ***pecan,*** Pecan	176	49.9
Ilex ***opaca,*** American holly	226–70	72.0
Juglans ***cinerea,*** Butternut	226–131	54.5
Juglans ***nigra,*** Black walnut	608	42.1
Liquidambar ***styraciflua,*** Red gum	72559	52.5
Liriodendron ***tulipifera,*** Yellow poplar	226–14	29.0
Magnolia ***fraseri,*** Fraser umbrella	226–122	67.5
Nectandra ***rhodei,*** Greenheart	.....	30.9
Nyssa ***sylvatica,*** Black gum	226–72	59.2
Platanus ***occidentalis,*** Sycamore	153	67.6
Populus ***deltoides,*** Cottonwood	368–1	73.4
Prunus ***pennsylvanica,*** Wild red cherry	226–45	78.2
Prunus ***serotina,*** Black cherry	197–33	64.6
Quercus ***alba,*** White oak	72919	26.5
Quercus ***Californica,*** California black oak	166	55.0
Quercus ***densiflora,*** Tan oak	15	76.0
Quercus ***garryana,*** Oregon oak	319–42	10.6
Quercus ***macrocarpa,*** Burr oak	211–27	48.5
Quercus ***michauxii,*** Cow oak	73009	64.9
Quercus ***nigra,*** Water oak	163	62.8
Quercus ***prinus,*** Chestnut oak	226–93	42.8
Rhus ***hirta,*** Staghorn sumach	211–	66.9
Robinia ***pseudacacia,*** Locust	226–131	48.9
Salix ***nigra,*** Black willow	132	78.1
Sassafras ***sassafras,*** Sassafras	226–127	57.3
Tilia ***americana,*** Basswood	73189	82.5
Ulmus ***pubescens,*** Slippery elm	211–6	55.9

the United States. Even such reputedly highly durable woods as cedars, cypress, junipers, sequoias, catalpa, greenheart, black locust, sassafras, white oak, black walnut, and black cherry are severely attacked, and in some instances completely destroyed.

The fact that commercial losses have so far been limited to coniferous timber is purely a matter of circumstance, not of potentialities. The writer has several records, however, in which broadleaf species have been severely attacked. In one case nail kegs, presumably constructed of broadleaf timber, rested on a decayed floor and were completely destroyed; in another instance an oak crate, containing a steel cylinder, was placed on the floor in an engine room of a Georgia planing mill, and although the floor was dry and showed no apparent rot, within three or four months the under part of the crate was rotten and the cylinder was covered with mycelium "as though it had been wrapped in cotton batting"; a third instance was of red oak flooring in a dwelling in Tennessee.

ECONOMIC FEATURES

Decay in Lumber Sheds and Stored Timber

The organism has an unprecedented record for destructiveness to timber used for building construction. The lumber industry is a particularly heavy sufferer. Twenty outbreaks in lumber storage sheds are known, most of them being very severe. Four of these were on the Pacific Coast, ranging from Seattle to San Francisco, and the remainder in the states of Alabama, Georgia, Louisiana, Mississippi, and eastern Texas.

It is impossible to trace the origin of these infections, but the conditions which have favored their development are obvious in most cases. Many of them had become widespread and very destructive before they were called to our attention. As a rule, the sub-floor timbers or the foundations for the lumber piles were infected first, the fungus then passing up into the flooring, where present, and ultimately into the base of the piles (Pl. 30, Fig. 4). Some of the sheds were built on swampy ground, and although the foundations were sufficiently elevated to secure air circulation, this did not reduce the moisture enough to prevent the spread of

the fungus from the soil upward. In such cases artificial drainage helped to correct the difficulty, but usually was not a remedy after the decay had once started. In other cases the foundation timbers were close to the ground, or in contact with it, a condition which frequently leads to decay in building timber, regardless of whether the soil is obviously moist or not.

Several instances have been noted where flooring in lumber sheds has been laid on stringers two to three inches thick resting directly on the soil or on various filling materials, such as cinders, sawdust, etc. This has invariably led to decay and frequently resulted in severe losses in lumber stocks stored thereon, for once the infection has passed upward into the flooring, it is readily transmitted to the stored material by contact. Kiln-dried stock appears to be as susceptible to infection as air-seasoned material.

In one case the mycelium was observed to pass upward to a height of five feet in a bundle of Douglas fir stepping end-piled on such a decayed floor. In other instances infection has been found running up posts in lumber sheds for six feet or more, and in some cases producing fructifications on them.

In only two instances has infection in the open yard been noted. In one of these cases about 20,000 feet of 6″ x 6″ sap pine were destroyed. This was piled on very low foundations. The fungus (probably *Poria incrassata,* since this was the organism prevalent in other parts of the yard) passed upward into the piles for 8–10 feet, although the timbers were separated by crossing strips 1 inch thick. After disposing of the infected wood for fuel, the new foundations were built somewhat higher and no further trouble was experienced with piles in the open.

The direct losses due to damage to lumber sheds and to the destruction or degrading of timber in storage are difficult to estimate, since detailed records are rarely kept.

At one retail yard in Alabama (Pl. 30, Fig. 4) the losses were estimated at between $1,000 and $2,000, occasioned by sporadic infections over a period of about seven years. This includes the total loss of two carloads of 6″ x 6″ pine timbers, about 20,000 feet b.m., just mentioned. At this yard considerable repair work was done both in the frame office building and in the storage sheds before the fungus was brought under control.

In a lumber yard at Houston, Texas, severe decay occurred in pine lumber close-piled in a shed for three to four months. About 15,000 feet of lumber were destroyed, as well as thirty to forty thousand heart cypress shingles. The total loss was about $500.

At another yard in south Georgia an estimated loss of $10,000 is reported.

The losses at certain other plants may be far in excess of these, judging from personal inspections made by the writer and information furnished by operators. The cost of replacing foundation timbers which have failed through decay is very often merged in the general upkeep, and this is particularly true where timbers here and there are replaced as failure occurs. Likewise considerable amounts of decayed stock are probably discarded, without particular attention, at the time piles are broken down. If a record were kept of the actual losses thus sustained, both in time and material, the results would be startling in many cases. In the aggregate the losses must run into the hundreds of thousands of dollars yearly when we take into consideration foundation timbers and other supports, flooring, stock, and the labor involved in repairs.

Decay in Buildings

The greatest damage, however, is not to the lumber dealer, but to the ultimate consumer of the infected products, for in all probability many of the outbreaks in buildings are directly traceable to infections starting in the lumber yard. While decayed stock would not normally be sold for structural purposes, nevertheless a dealer does not usually cull his product more closely than absolutely necessary to satisfy business standards. Incipient infections could readily pass the usual inspection and would constitute just as severe a menace as the more conspicuous decay.

The fungus is known to be widely distributed in buildings throughout the country (Pl. 30, Figs. 5 and 6). The writer has investigated, or has records of, more than thirty cases. The organism is a domesticated species and reaches its best development in buildings. Its occurrence in the woods is comparatively rare, but there is little doubt that infections in lumber yards and buildings have originally come from the forest. Undoubtedly as

our knowledge of the fungous flora of the forest increases a wider distribution and prevalence of the organism will be demonstrated.

At the present time infections in buildings (outside of lumber storage sheds) are known from at least thirteen states, principally in the southern United States and Pacific Coast region. Many of these buildings are frame residences, but other structures, such as stores, factories, warehouses, and churches, fall a ready prey as well. The damage to many of these buildings has been extensive.

In all cases the outbreaks have started beneath the first floor, particularly where this has been placed over moist ground. It is not necessary, however, that the sub-floor timbers and floors be close to the ground, for in the moist climate of the Gulf states houses built over apparently dry sandy soil and well ventilated beneath have suffered heavy losses. In frame buildings the fungus spreads from the sub-floor timbers up the walls and usually first becomes evident by the rotting and shrinking of baseboards, panels, wainscoting, door casings, etc. The shrinkage, and consequent opening of the joints, exposes the whitish mycelium behind. These are very conspicuous features.

Not only does the fungus run up the walls behind interior finish and between the studding of plastered walls (Pl. 30, Fig. 5), but it will also readily pass up simple interior partitions consisting of half-inch ceiling lumber nailed on either side of upright strips, and in one case it was found extending up a partition of single thickness half-inch beaded stock placed vertically. In one dwelling the organism passed up a double interior wood partition to the ceiling of the room, a height of about ten feet. In another case it extended up a similar partition between two rooms, each containing a coal stove operated during the entire winter, for a distance of six to eight feet. In one of the rooms the stove was set as close to the partition as safety would permit.

How the fungus can obtain sufficient moisture under such circumstances has not been determined, as rhizomorphs are usually lacking in such places. Invariably, however, rather compact sheets of fan-shaped mycelium form within the wall cavities and this may function in water conduction. Likewise, the further possibility of water production by the disintegration of the fiber in the decay processes offers a hypothesis worthy of further investigation.

Not alone does the fungus destroy the timber of the buildings, but it will also readily infect objects in contact with the decayed wood. Thus window sash, doors, wall board, nail kegs, tarred roofing (Pl. 30, Fig. 3), asphalt shingles, cement-asbestos shingles, galvanized fencing wire, and various documents and minor items stored in infected buildings have been destroyed or damaged.

The fungus works very rapidly and for this reason has occasioned serious concern in more than one household. In some instances tenants have complained of the floors breaking through in walking about, or the post of a bed has crushed through, or a door has fallen from its hinges. These events are at the least disconcerting, although they may not be particularly dangerous.

At the University of Florida a large floor area in one of the modern brick buildings was destroyed and several large uprights attacked within two years. In a brick store building six years old at Kissimmee, Florida, the floor had rotted out, and the new flooring put in had also rotted through in places within a year after replacement. A frame residence at St. Lucie, Florida, suffered severe loss in three years, and by five years about one fourth of the house was visibly affected. In a residence at Thomasville, Georgia, decay started in a property twenty years old and extended to a height of about 14 feet, rotting sills, joists, studding, siding, etc., necessitating repairs amounting to $850. A cottage at Louisville, Kentucky, built about three years, suffered badly from the decay of sub-floor timbers, flooring, and casings, with a loss of about $150. A residence in Memphis, Tennessee, required several hundred dollars for repairs. In a fine residence at Shreveport, Louisiana, a considerable part of the front wall and 750 feet of flooring had to be replaced within three years after construction, necessitating an expense of about $3,000. In a store at Baton Rouge, Louisiana, heart cypress ceiling laid over a brick wall lasted but six months.

The facts at hand thus indicate that *Poria incrassata* is a particularly destructive and rapid-growing organism which attacks practically all species of wood. The only timbers which have been observed rotting under natural conditions are, with the exception of the hardwood material previously mentioned, species of south-

ern pine, Douglas fir, and cypress. This is the case since these timbers are the principal structural material in the regions where the fungus prevails. The organism is spreading rapidly, mainly throughout the southern and Pacific Coast states. It is becoming more or less epidemic in character and is apparently introduced into new buildings in certain cases through the use of infected lumber. The situation is becoming so acute that it is necessary to take immediate steps to bring the many infections under control and eradicate them wherever possible.

The severely decayed wood is brown and breaks up into irregular chunks by the formation of shrinkage cracks both across and in the direction of the fiber, the crevices frequently containing sheets of white mycelium.

Since the organism apparently thrives under conditions which at times are not favorable to the growth of most other fungi, it assumes special importance in buildings, and recommendations for control must take into consideration all the factors in the life history.

CONTROL MEASURES

Prevention

In controlling this fungus our first attention should be directed toward preventing new infections. The two main points to consider in this connection are, first, an improvement of the sanitary condition of lumber yards, particularly with respect to the presence of infected or rotting debris about the yard which may serve as a source of infection, and, second, suitable changes in building design, so as to eliminate, as far as possible, the more favorable conditions for fungus attack.

In every case timber storage yards should be kept as free as possible of all decayed material and weeds should be kept down, as these impede free air circulation. Surfacing the soil with cinders is always highly advisable and wherever the yards are located on wet ground, or where subject to periodic wetting, they should be properly drained. Lumber storage sheds can be rendered fungus-proof by using for the foundations, both for the sheds and the piles, either such substances as concrete, brick, or stone, or

timber *thoroughly* treated with an antiseptic, such as coal-tar creosote, zinc chloride, or sodium fluoride. If it is not considered feasible to make the entire foundation of one or the other of these substances, at least the piers or blocking upon which the supporting timbers rest should be of this type of material. This will prevent the fungus from passing upward from the soil. The foundation should be 12 to 18 inches off the ground and fully ventilated beneath from all sides. When the piles are erected every bit of suspicious wood should be carefully culled and either segregated or destroyed. This is essential, since decay may be started in a pile by the inclusion of even a trace of living fungus.[4]

Since timbers often apparently become infected in the lumber yard, the above precautions will reduce to a considerable extent outbreaks of the fungus in buildings. In addition, however, the consumer has several points to consider in the proper inspection and use of timber after it comes into his hands. These may be summarized as follows:

1. All timber and organic products used in building construction should be carefully inspected for the presence of infection or decay, and suspected material should be rejected.

2. Floors should never be laid directly on the soil or over brick or concrete in basements unless the timber has first been given a thorough treatment with an efficient antiseptic, such as coal-tar creosote, zinc chloride, or sodium fluoride.

3. Other basement or sub-floor timbers which are more or less subjected to moisture should be given some measure of protection by dipping the timbers, spraying, or giving them two to three brush applications with hot coal-tar creosote, or where the color and odor of this substance are objectionable, with a 6 per cent water solution of zinc chloride or a 4 per cent solution of sodium fluoride.

4. Timbers should not be embedded in concrete, brick, or stone walls without leaving ventilation around the ends of the timber by suitable boxing, and even then one of the above preservatives should be carefully applied, using as much preservative as the timber will absorb.

5. If for any reason it is necessary to use untreated timber for the lower floor supports heart material of naturally durable species should be carefully selected. It should be kept in mind, however, that even the highest grade heartwood is far from being immune to decay once this fungus becomes started. The sapwood of none of our commercially available species is suitable for this purpose, and is only to be recommended when thoroughly treated. It can then

[4] A further discussion of this subject will be found in United States Department of Agriculture Bulletin 510, "Timber storage conditions in the eastern and southern states with reference to decay problems," 1917, by the present writer. This bulletin is being revised and will soon be reissued.

be advantageously used on account of the good absorptions and penetrations secured. Dipping, spraying, or brush applications are not dependable where much sapwood is involved.

6. Preference should always be given to thoroughly dry timber. When used in a green or moist condition wood is very apt to become infected, and does not take preservative treatment readily by any of the non-pressure processes.

7. Ample ventilation of basements is very desirable, as a general rule, although where the basement air is somewhat warmer than the outside air, and highly humid, the entrance of the colder outside air may lower the dew point sufficiently to cause condensation of water on the timber. This will naturally lead to even more rapid decay than formerly.

ERADICATION

When the fungus has once gained entrance the only feasible remedy is complete eradication of every trace of infection. This must be thorough. Timbers must be cut back at least two feet beyond all trace of decay to insure success. If the job is not thorough the organism will continue to develop. After eliminating and destroying any of the stored lumber which is visibly infected, the remainder of the stock in the immediate vicinity of the infection area can be further safeguarded by running it through the dry kiln, where such equipment is available. The usual approved methods for kiln-drying coniferous stock will kill any traces of fungus which may have been overlooked, particularly in 1- and 2-inch stock. For larger timbers the treatment will have to be carefully supervised and tested for efficacy, in order to be sure of success.

Sound timbers adjacent to the infection should be surface-treated as just indicated and the adjacent masonry and soil sprinkled or sprayed with the same antiseptic. The timber used in replacement should be selected and handled in the manner already discussed for new construction. Footings or piers in contact with the soil should be either of masonry or thoroughly treated timber. In cases where flooring in contact with the ground has decayed, and the soil is thus thoroughly infected, either concrete or thoroughly treated timber is likewise indicated.

It should be kept in mind that no light preservative treatments will offer full protection, and in no case will they eradicate infections already in the wood.

INVESTIGATIONS IN FOREST PATHOLOGY, BUREAU OF PLANT INDUSTRY,
IN COÖPERATION WITH THE FOREST PRODUCTS LABORATORY,
MADISON, WISCONSIN

DESCRIPTION OF PLATES

PLATE 28

Fig. 1. A normal olive-gray fructification on the underside of pine flooring in a warehouse for tarred roofing paper in eastern Texas. Photographed in a fresh condition.

Fig. 2. A fresh olive-gray fruit-body from the underside of Douglar fir flooring in an open lumber storage shed at Seattle, Washington. (See also Pl. 29, Fig. 1.)

Fig. 3. Section of fructification shown in Fig. 2, showing well-developed pores about 1 cm. long.

Fig. 4. Abortive brownish-black fructification on pine partition separating a servants' toilet from an adjoining woodshed at Gainesville, Florida. Fungus fruiting in the partially illuminated shed. Note the thick subiculum of vertically arranged hyphae which become very conspicuous when the fungus cracks from drying.

Fig. 5. Abortive brown liver-like fruit-body from the upper surface of pine floor planks in a cotton warehouse in Mississippi.

Fig. 6. Abortive thin brown fruit-body on pine wall sheathing in a small workshop at Riderville, Alabama.

Fig. 7. Old blackish-brown fructification on the reverse side of sheathing similar to that shown in Fig. 6.

Fig. 8. A thin young cinnamon-buff fruit-body on the foundation timbers in one of the temporary government buildings in Washington, D. C. This building was erected during the recent war and has already failed at several points as a result of this infection.

PLATE 29

Fig. 1. An old dry fruit-body on the underside of Douglas fir flooring in an open lumber shed at Seattle, Washington.

Fig. 2. White strand-like mycelium and small white to brown rhizomorphs on the underside of pine flooring in a warehouse for tarred roofing paper in eastern Texas. (See also Pl. 28, Fig. 1.)

Fig. 3. Large brownish rhizomorphs closely embedded in a mycelial sheet on the under surface of a pine floor board. This floor was laid on 2″ x 4″ timbers placed on edge on a brick pavement in the basement of a church at Natchez, Mississippi.

Fig. 4. Cross section of large rhizomorph under low magnification. The openings toward the center are conducting tubes.

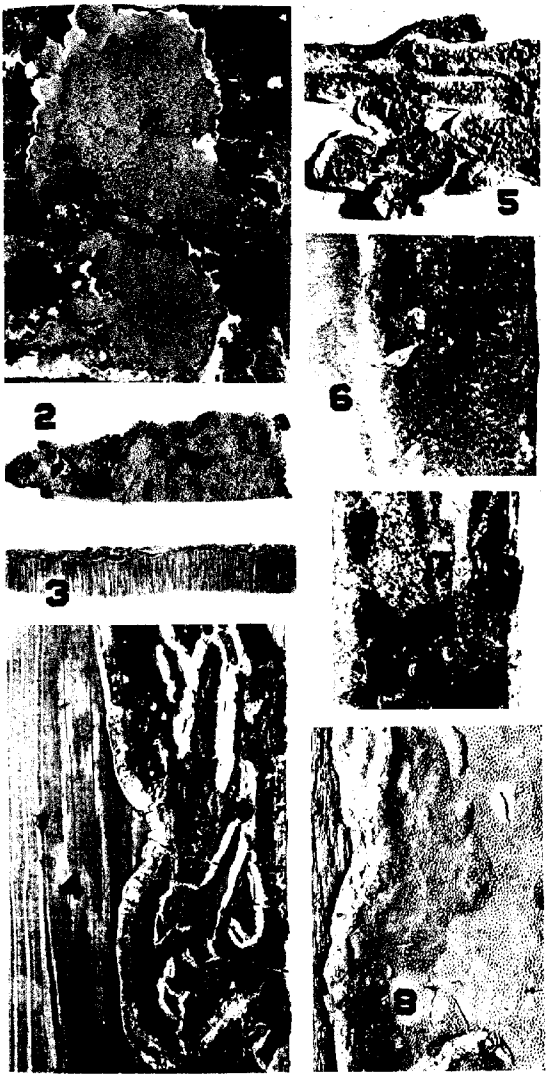
Fig. 5. Central portion of same rhizomorph under higher magnification than in Fig. 4.

Fig. 6. Spores of *Poria incrassata*.

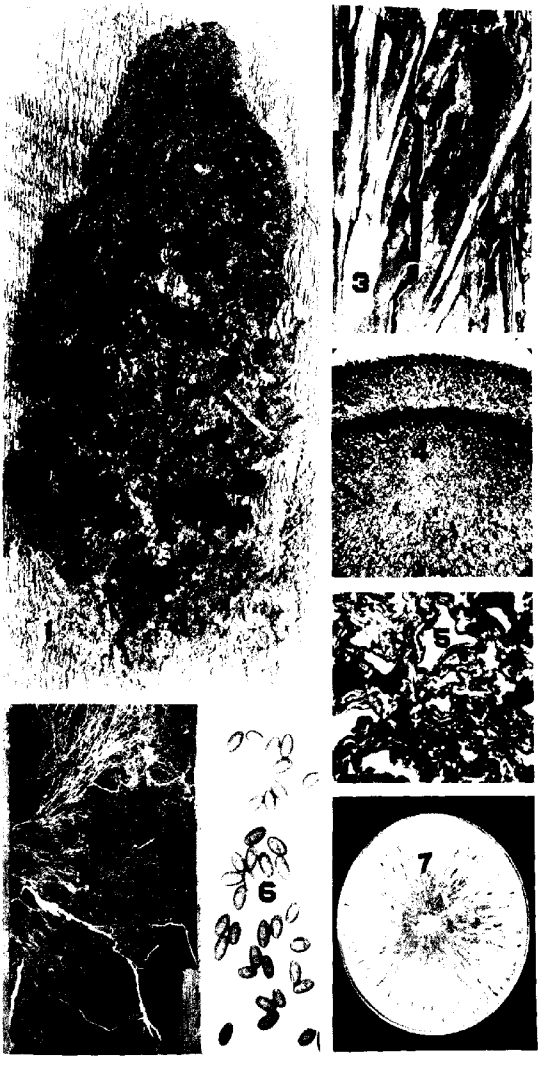
Fig. 7. A Petri-dish culture of *Poria incrassata* grown for 22 days at 30° Centigrade.

PLATE 30

Fig. 1. Heart cypress shingles showing an abundance of white to yellowish fan-shaped mycelium. The fungus coated the shingles throughout the bundles



PORIA INCRASSATA (B. & C.) BURT



PORIA INCRASSATA (B. & C.) BURT

PORIA INCRASSATA (B. & C.) BURT

and in a short time totally destroyed 30 to 40 thousand shingles at a retail lumber yard in Houston, Texas.

Fig. 2. A pure culture of *Poria incrassata* in a 2-liter Erlenmeyer flask prepared for testing the durability of various woods. Note the strandlike growth of the fungus.

Fig. 3. Mycelium on the surface of tarred roofing paper stored over an infected floor. The fungus invaded the lower end of the rolls and destroyed a considerable amount of the stock.

Fig. 4. An infected pine post and stringers in an open lumber shed at a retail lumber yard in Birmingham, Alabama. The fungus has run upward to the second bin, a distance of 5 to 6 feet. New sound planks were, in some cases, piled in close contact with the diseased posts. The infection will thus be transmitted in the course of a few days to every plank in the pile. The losses on this yard amounted to $1,000 to $2,000.

Fig. 5. Infection within a plastered partition wall in a church at Kansas City, Missouri, after one side of the wall has been torn away. A large area of flooring laid over cement was also rotted.

Fig. 6. Pine floor in the basement of a church in Natchez, Mississippi. The floor is laid on 2" x 4" pine stringers placed edgewise and resting on a brick pavement. This timber gave very short service.

FLORIDA FUNGI—I

W. A. MURRILL

A number of fungi were picked up by me at various places in Florida during March, 1923, when I was fortunate enough to be able to make a collecting trip through portions of the state. As the season was very dry, few fleshy fungi were seen, even in the hammocks, where most of my time was spent. Instead of repeating the word "hammock" in my locality notes, the reader will please understand it after most of the places mentioned, like Deering, Snapper Creek, Brickell, Royal Palm, and Brooksville. At Tarpon Springs and New Smyrna the collecting grounds were mostly dense woods along streams or in low places. The Florida pine lands were much too dry when I saw them to yield anything of special mycological interest.

AGARICACEAE

DROSOPHILA APPENDICULATA (Bull.) Quél. Brooksville.
LENTINUS CRINITUS (L.) Fries. Brooksville, New Smyrna, Royal Palm.
LENTINUS STRIGOSUS (Schw.) Fries. Brooksville.
LENTINUS VELUTINUS Fries. Brooksville.
PLICATURA LATERITIA (Berk. & Curt.) Murrill. Tarpon Springs.
PLUTEUS CERVINUS (Schaeff.) Quél. Brickell, Brooksville.
SCHIZOPHYLLUS ALNEUS (L.) Schroet. Tarpon Springs.

PILEATE POLYPORACEAE

BJERKANDERA ADUSTA (Willd.) P. Karst. Brooksville, New Smyrna.
CERENELLA FARINACEA (Fries) Murrill. New Smyrna, Royal Palm.
CERENELLA RAVENELII (Berk.) Murrill. New Smyrna, Royal Palm.
CORIOLELLUS SERIALIS (Fries) Murrill. Tarpon Springs.
CORIOLOPSIS CROCATA (Fries) Murrill. Brickell, Royal Palm.
CORIOLOPSIS RIGIDA (Berk. & Mont.) Murrill. Royal Palm.
CORIOLUS BIFORMIS (Klotsch) Pat. Brooksville.
CORIOLUS BRACHYPUS (Lév.) Murrill. Deering, Snapper Creek.
CORIOLUS MAXIMUS (Mont.) Murrill. Brickell.
CORIOLUS MEMBRANACEUS (Sw.) Pat. Deering, New Smyrna.
CORIOLUS NIGROMARGINATUS (Schw.) Murrill. Brooksville.
CORIOLUS OCHROTINCTELLUS Murrill. Deering. Apparently an abnormal, stipitate form of this Mississippi species.

CORIOLUS PINSITUS (Fries) Pat. Brickell, Deering, Snapper Creek.

CORIOLUS SERICEOHIRSUTUS (Klotsch) Murrill. On red cedar at New Smyrna. Very nearly related to *C. pinsitus*.

CORIOLUS SECTOR (Ehrenb.) Pat. Brooksville, Deering, Snapper Creek, Tarpon Springs.

CORIOLUS VERSICOLOR (L.) Quél. Brooksville, New Smyrna.

CYCLOPORELLUS IODINUS (Mont.) Murrill. Brooksville, Royal Palm, Snapper Creek.

DAEDALEA AMANITOIDES Beauv. Brooksville.

DAEDALEA CONFRAGOSA (Bolt.) Pers. Brooksville.

ELFVINGIA TORNATA (Pers.) Murrill. Brooksville, Deering, Snapper Creek.

ELFVINGIELLA MARMORATA (Berk. & Curt.) Murrill. On decayed spot in trunk of living live-oak on a street in Brooksville.

FOMES ROSEUS (Alb. & Schw.) Cooke. On red cedar at New Smyrna.

FOMITELLA SUPINA (Sw.) Murrill. Brooksville, Deering, Royal Palm.

GANODERMA SUBINCRUSTATUM Murrill. Coconut Grove.

GANODERMA SULCATUM Murrill. Abundant on cabbage palmetto at New Smyrna and also found on the same host near Tarpon Springs.

GLOEOPHYLLUM HIRSUTUM (Schaeff.) Murrill. Royal Palm, Tarpon Springs,

GLOEOPHYLLUM STRIATUM (Sw.) Murrill. Brooksville.

HAPALOPILUS GILVUS (Schw.) Murrill. Brooksville, Deering, Tarpon Springs.

HAPALOPILUS LICNOIDES (Mont.) Murrill. Brooksville, Deering, Royal Palm, Snapper Creek.

INONOTUS FRUTICUM (Berk. & Curt.) Murrill. Deering.

LENZITES BETULINA (L.) Fries. Brooksville.

POGONOMYCES HYDNOIDES (Sw.) Murrill. Brickell, Brooksville, Deering, Royal Palm, Snapper Creek, Tarpon Springs.

POLYPORUS ARCULARIUS (Batsch) Fries. Brooksville, New Smyrna.

PYCNOPORUS SANGUINEUS (L.) Murrill. Brooksville, Deering, New Smyrna, Royal Palm, Snapper Creek.

PYROPOLYPORUS CALKINSII Murrill. Resupinate form on live-oak near Tarpon Springs.

PYROPOLYPORUS DEPENDENS Murrill. Common on live-oak trunks at Brickell and Deering.

PYROPOLYPORUS LANGLOISII Murrill. Snapper Creek. Apparently a form of this Louisiana species which dried up and became indurate before fully expanding.

Trametes amygdalinus (Berk. & Rav.) comb. nov. (*Polyporus amygdalinus* Berk. & Rav.; Berk. Grevillea 1: 49. 1872.) Described from South Carolina on oak, and sent to me in fine examples from Alabama by Dr. R. P. Burke. I found it on old live-oak logs in the big hammock at Brooksville. *Trametes cubensis* (Mont.) Sacc. is probably its nearest relative. The beginner might possibly confuse it with *Laetiporus sulphureus*, but it is not brilliantly colored and the context is not rigid when dry.

NEW YORK BOTANICAL GARDEN

CORDYCEPS SPHINGUM (SCHW.) IN THE PHILIPPINES

ALBERT W. C. T. HERRE

The accompanying figures are of a sphingid moth belonging to the genus *Acosmeryx* Boisd., according to Mr. W. Schultze, entomologist of the Bureau of Science. The moth is a mere chitinous shell, its singular appearance being due to the growth of a well-known insect-destroying fungus, *Cordyceps sphingum.* The long spikes protruding in every direction from the moth are the ascophores, or fruiting branches, of the fungus. Through the kind-

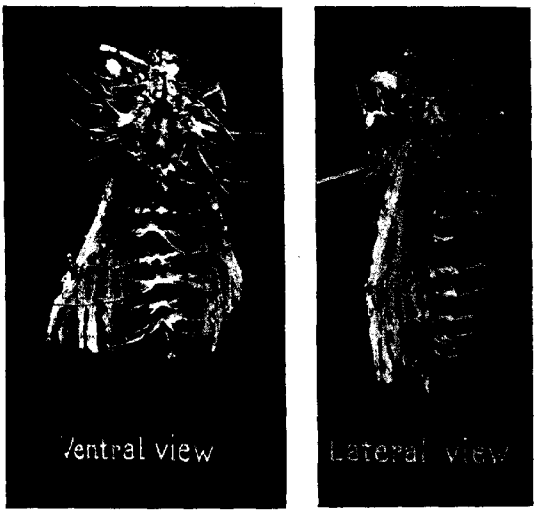


FIG. 1. *Cordyceps sphingum.*

ness of Father Sanchez, S. J., the Bureau of Science has received a specimen collected at Camp 2, on the Benguet road, Mountain

Province, by Señor Ferreira. It is thoroughly typical, agreeing in all essentials with Tulasne's [1] figures.

This species occurs on sphingid moths and on Orthoptera (locusts and katydids) from North Carolina to Brazil, being common in the West Indies. It has also been reported from Darjeeling, India, on two moths of the *Noctuidae, Spirama retorta,* and a species of *Hypena.* European records from Scotland and Switzerland are more or less doubtful, as are certain records from the northern United States. As a general rule mycologists have called every Isaria-like fungus parasitic on a moth *Isaria* or *Cordyceps sphingum,* without comparison with authentic herbarium material.

The occurrence of this striking-looking insect-destroying fungus in the mountains of Northern Luzon adds greatly to our knowledge of its distribution and is a notable find.

BUREAU OF SCIENCE,
MANILA, P. I.

1 Tulasne, Sel. Fung. Carpol., 3 (1865), 12, *Tab. I, figs. 1 and 2.*

INDEX TO VOLUME XV

New names and the final members of new combinations are in **bold face type**